

Measurement of Venous Blood Flow in the Lower Limbs: Prevention of Deep Vein Thrombosis during Prolonged Sitting

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Abstract. The venous blood flow during stretching and deep breathing in the sitting posture was examined in the present study. First, an inguocrural venous blood flow was measured using the Doppler method. It was confirmed that the blood flow velocity significantly increased during stretching with deep breathing. Second, the peripheral blood circulation in the lower limbs was evaluated during a 60 min sitting session using a near infrared spectroscopy method. It was confirmed that stretching while sitting restrained the reduction of blood flow. These results effectively showed an increase in the venous return. Therefore, we suggest that stretching and deep breathing can be used sometimes as preventive measures for deep vein thrombosis during prolonged sitting.

Keywords. Venous blood flow, Near infrared spectroscopy, Deep vein thrombosis.

1. Introduction

It has been reported that some airline passengers may develop blood clots (thrombus) in the deep vein, often in the lower part of the leg, due to sitting for a long period of time without mobility. This condition is medically known as deep vein thrombosis (DVT). If thrombus fragments break off and lodge in other areas of the body, such as lungs, they may cause a possibly fatal pulmonary thromboembolism when the person stands and begins to walk after being immobile for a long period of time. DVT has been termed, "Economy class syndrome," because some cases have been reported in airline passengers who traveled in the economy class. However, DVT is not restricted to a particular class of airline travelers, and may affect any traveler in other classes or in other forms of transport, including cars, trains, vehicles, if they are in the sitting position for a long period of time without any form of exercise. Recently, a similar condition termed "Traveler's thrombosis" has been reported. Even theater visitors and visual display unit (VDU) workers can be at a risk. The mechanisms of intravascular thrombus formation are still

regarded as being based on the Virchow's triad: 1) Venous stasis; 2) Hypercoagulability; 3) Vein wall damage. Figure 1 which based on it shows the risk factors in an aircraft cabin. Immobility, shifts of body fluid, orthostatic stress, and compression of the popliteal vein at the edge of the seat are some conditions arising from long-term, cramped sitting posture that might lead to the pathological conditions described by Virchow (1954). The decrease in venous return that is associated with immobility, reduced respiration, and legs flexion (a hip joint, knee joint angle) during prolonged sitting, has also been described as a factor that causes the venous stasis (Kinjo, 2003). To prevent DVT, it has been recommended that travelers should be advised drink adequate fluids, avoid smoking and alcohol, remove tight clotting and to take exercise such as walking and stretching their limbs (e.g. Landgraf et al., 1994; Morio, 2002). We are of the opinion that apart from these measures, stretching of the back is also an useful strategy. Stretching may promote deep breathing and venous return from the lower limbs. However, sufficient scientific evidence related to the effects of these recommendations in an aircraft cabin is not available.

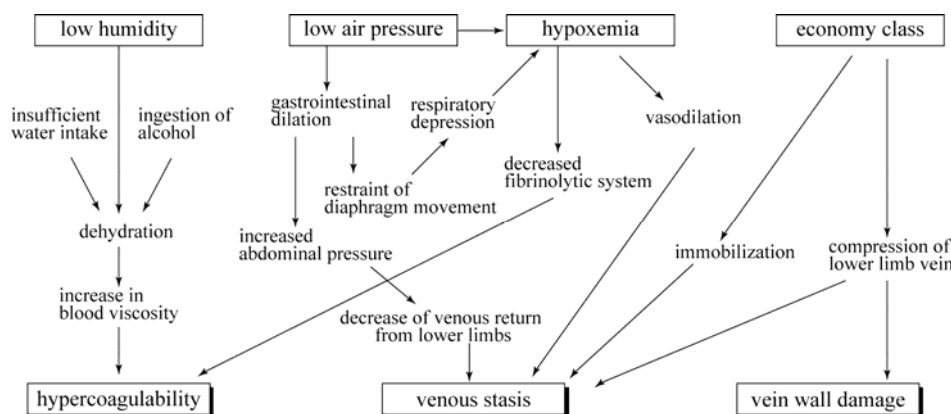


Figure 1. Risk factors of deep vein thrombus in an aircraft cabin (Source: Eklof et al., 1996; Morio, 2002)

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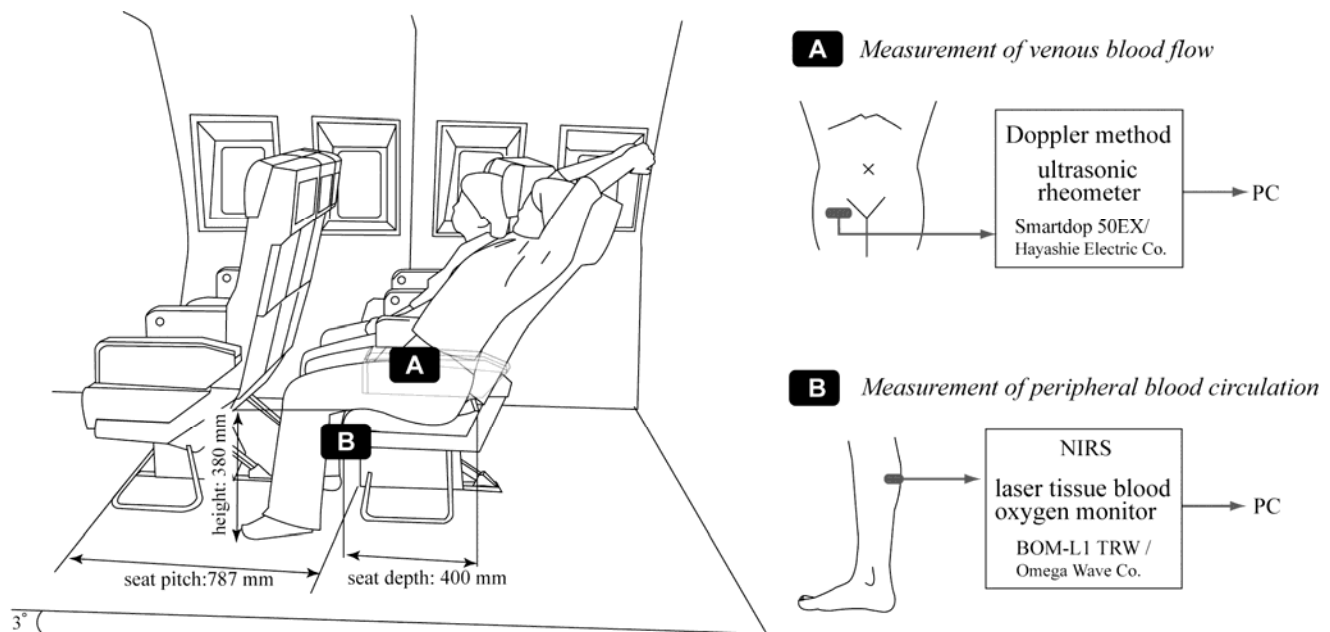


Figure 2. Experimental environment and test items

The objective of this study was to gain a better understanding of the blood flow changes that occur in the sitting posture in passenger seats. The questions addressed in this study are: 1) Do changes occur in venous return under different sitting conditions?; 2) Will periodic stretching of the back have an preventive effect on the peripheral blood circulation in the lower limbs during prolonged periods of sitting?

2. Material and Methods

2.1. Experimental environment

The experiments were carried out in a mock-up of a Boeing 767 aircraft cabin (Figure 2). The experimental seat was adjusted for the Japanese body size. The backrest of the seat was improved so that the subject's back was easily extendable, and it consisted of two independent supports to the upper (thoracic) and lower (lumbar) back. The following two investigations were designed for understanding the blood circulation during sitting.

2.2. Experiment 1: effect of posture conditions and respiration on venous blood flow velocity

The aim of the first experiment was to investigate the effect of the interaction between posture conditions and respiration on venous blood flow velocity in five healthy males. The venous blood flow velocity was measured using an ultrasonic rheometer (Smartdop 50EX, Hayashie Electric Co., Japan). The measurement was carried out on the right inguino-cru-ral vein. The experimental condition is shown in Table 1. For the upright position the backrest angle was fixed at 95 degree, for the reclining position it was fixed at 105 degree, and for the stretch position it was fixed at 95-115 degree by adjusting the upper part. In addition, the subject was made to sit with normal breathing condition and deep breathing condition, under the former three posture conditions.

Table 1. Conditions of experiment 1

Posture	Respiration		
		Normal breathing	Deep breathing
	Upright position	Group-1	Group-4
	Reclining position	Group-2	Group-5
	Stretching	Group-3	Group-6

2.3. Experiment 2: effect of stretching on peripheral blood circulation during prolonged sitting

The effect of stretching on peripheral circulation in the lower limbs during prolonged sitting was examined in this study using the near-infrared spectroscopy (NIRS). The experiment was performed on ten healthy, middle and old aged females (mean age, 52.9 ± 7.9 years; weight, 61.4 ± 6.5 kg; stature, 155.8 ± 5.3 cm; body mass index, 25.3 ± 2.5) under two conditions: "quiet sitting" condition and "sitting with stretch" condition. Under the two conditions, the subjects were made to sit for 60 min. In the "sitting with stretch" condition, the subject stretched for 30 sec during a time interval of 20 min, 40 min, and 60 min from the point when the sitting posture was attained. NIRS was used to measure and evaluate tissue blood oxygen saturation non-invasively and continuously. Using NIRS, it is possible to measure the changes in oxygenated hemoglobin (OxyHb), deoxygenated hemoglobin (DeoxyHb), and total hemoglobin (TotalHb) in tissues. During the sitting posture, peripheral muscle oxygenation was continuously measured in the right gastrocnemius using a laser tissue blood oxygen monitor (BOM-L1TRW, Omega Wave Co., Japan). This instrument uses three laser diodes (780, 810, and 830 nm), and calculates tissue levels of OxyHb, DeoxyHb, and TotalHb according to the Beer-Lambert law. The absorption coefficient of hemoglobin at each wavelength is based on the data reported by Matcher et al. (1995).

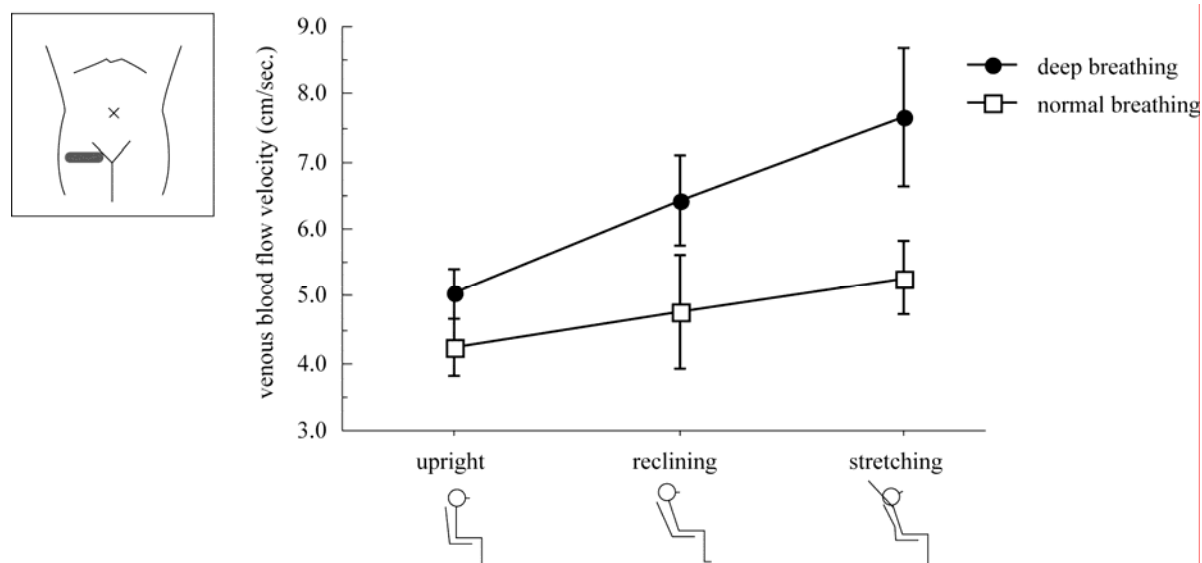


Figure 3. Venous blood flow velocity under each condition

It has been examined that NIRS parameter reflected the systemic oxygenation consumption (VO_2) in the local muscle by Kawaguchi et al. (2001). For taking the measurements, the distance between the incident point and the detector was at 13–30 mm. They were fixed with a tape after shielding with a rubber sheet and vinyl. The data were input into a personal computer at sampling frequency of 60 Hz. The analytical data was calculated one frame per one sec.

3. Results and Discussion

3.1. Results of experiment 1

Figure 3 shows the result of venous blood flow velocity in each of the condition. A two-way factorial ANOVA was applied to maximum velocity of venous blood flow. The main effect of respiration was significant ($F = 8.23$ $p < 0.01$), and the main effect of posture was also significant ($F = 3.56$ $p < 0.05$). These results show that the effects of posture and respiration on the venous blood flow velocity were different. It was found that the venous blood flow velocity significantly increased during stretching with deep breathing, which was slowest during the upright position. It is considered that the combination of stretching and deep breathing further increased the venous return. The reclining position that adjusts the hip joint angle to an obtuse angle may increase the venous return and reduce the inguocrural venous blood pressure from inguinal ligament or fat.

3.2. Results of experiment 2

Figure 4 shows the average values of the blood circulation in the gastrocnemius muscle. The average amplitude under each condition after 20 min was converted into a relative value by using the mean score from 18 min to 20 min as the baseline. A two-way factorial ANOVA was applied to the category variables that were time points, and each condition was applied to scores of OxyHb, DeoxyHb, and TotalHb. A significant interaction was found between each factor (OxyHb, $F = 2.46$, $p < 0.05$; DeoxyHb, $F = 3.30$, $p < 0.01$; TotalHb, $F = 4.25$, $p < 0.01$). This result shows that the blood circulation was significantly different between the “quiet

sitting” condition and the “sitting with stretch” condition. No particular trend was observed in the OxyHb levels, and the DeoxyHb and TotalHb levels gradually decreased under the “quiet sitting” condition. This trend shows that the peripheral blood flow decreased because the leg muscle pump was not active under “quiet sitting” condition. On the other hand, OxyHb and TotalHb levels increased after stretching during the 20 min time interval. It is considered that the inflow from arterial blood increases due to stretching. The DeoxyHb level decreased after stretching and was recovered later. It is considered that the outflow of venous blood increases and OxyHb is converted into DeoxyHb by gastrocnemius muscle for contraction or circulation regulation function. This finding suggests that exercise during prolonged sitting restrains the reduction of blood flow in the lower limbs and has a preventive effect on DVT.

The clinical DVT cases of Japanese travelers were females older than 40 years, smaller than 160 cm, and body mass index 23.8 ± 2.2 reported by Morio et al. (2000). The female subjects on experiment 2 were similar to this clinical example and were considered high-risk group. The results of this experiment suggest evidence that stretching is useful for high-risk group.

4. Summary

The effect of physical exercise on blood flow in the lower limbs during a sitting posture was examined in the present study. The results showed that when back stretching and deep breathing were both carried out by a person, a significant increase was observed in the inguocrural venous blood velocity using the Doppler method. The reclining position that adjusts the hip joint angle to an obtuse angle increases venous return. Furthermore, the peripheral blood circulation in the gastrocnemius was measured during a 60 min sitting session using the NIRS. The results show that no particular trend was observed in the OxyHb levels, and the DeoxyHb and TotalHb levels gradually decreased under the “quiet sitting” condition. On the other hand, OxyHb, TotalHb, and DeoxyHb levels increased under the “sitting with stretch” condition.

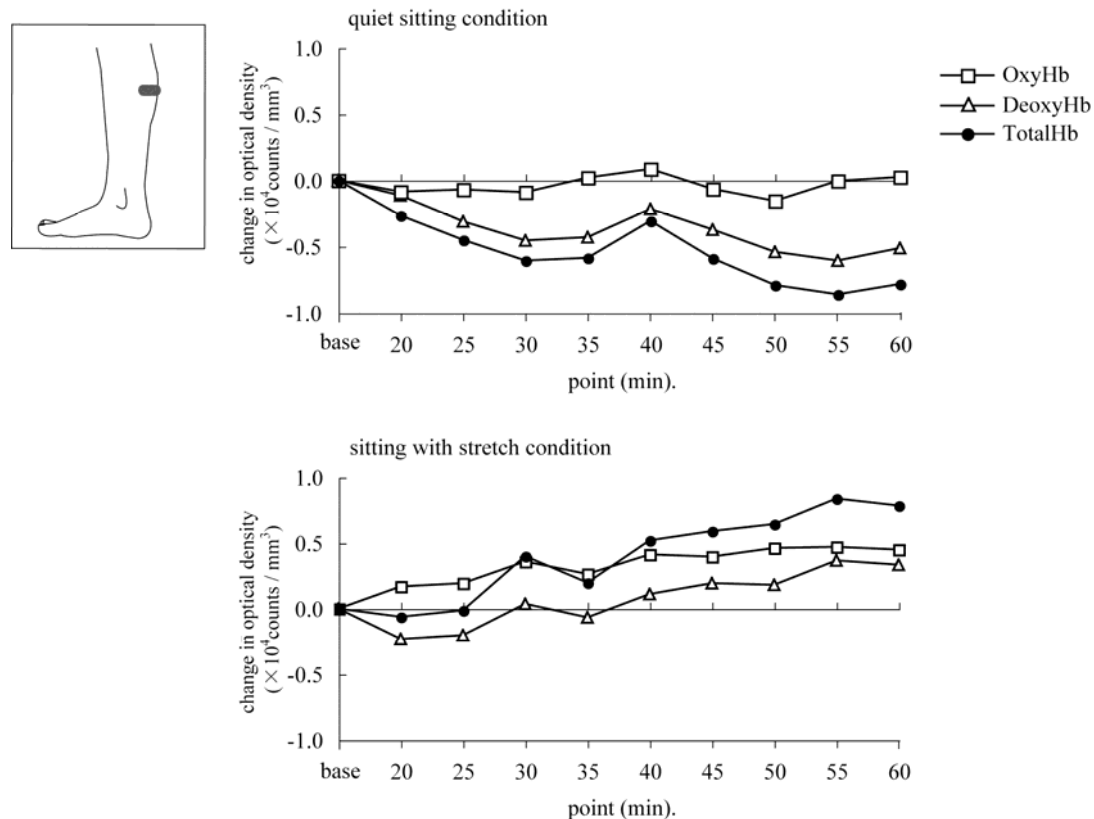


Figure 4. Peripheral blood circulation (OxyHb, DeoxyHb, and TotalHb levels) in the gastrocnemius under each condition.

These findings suggest that exercise during prolonged sitting restrains the reduction of venous return from lower limbs and has a preventive effect on DVT. As a preventive measure for DVT, leg exercises are commonly recommended. The authors were of the opinion that apart from leg exercises, back stretching was also a useful measure. The above results support this idea. DVT affects not only individuals working in an aircraft cabin but may also affect VDU workers in an office or any traveler using any forms of transport, including cars and trains, if they are in the sitting posture for a long period of time without any exercise. To prevent DVT in daily life, stretching and deep breathing are recommended along with leg exercises during a sitting posture.

5. Acknowledgments

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